Journal of Civil Engineering and Environmental Technology
Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 2, Number 7; April-June, 2015 pp. 621-625

http://www.krishisanskriti.org/jceet.html

Recycled Glass as a Partial Replacement for Fine Aggregate in Self Compacting Concrete

R. Vikraman[*1] and M. Nithya[2]

*[*1]Student, Department of Civil Engineering (PG), Dhirajlal gandhi college of technology, Salem*
[2]Department of Civil Engineering, Dhirajlal gandhi college of technology,
E-mail: [1]vikramvikraman@gmail.com, [2]harshasanthosh1710@gmail.com

Abstract—*Glass has been indispensable to man's life due to its properties, including pliability to take any shape with ease, bright surface, resistance to abrasion, reasonable safety and durability. Waste glass creates serious environmental problems, mainly due to the inconsistency of waste glass streams. With increasing environmental pressure to reduce solid waste and to recycle as much as possible, the concrete industry has adopted a number of methods to achieve this goal. Self-Compacting Concrete (SCC) may lead to evolution of a more quality controlled concrete, assuring a better workability and avoiding human errors with regard to mixing and workability issues. On the other hand, it resolves the problem of noise and vibration during installation. The object of this research work is to study the effect of using recycled glass waste, as a partial replacement of fine aggregate, on the fresh and hardened properties of Self-Compacting Concrete (SCC). A total of 6 concrete mixes were produced with cement contents 416 kg/m^3 at W/C ratio of 0.45 In this investigation it was proposed that the use of fly ash as cement replacement material of 10% and Recycled glass was used to replace fine aggregate in proportions of 0%, 10%, 20%, 30%, 40%, and 50%.*

1. INTRODUCTION

Glass is one of the oldest man-made materials. It is produced in many forms, including packaging or container glass, flat glass, bulb glass, and cathode ray tube glass, all of which have a limited life in the forms in which they are produced. Hence, glass need to be reused/recycled in order to avoid environmental problems that can be created, if they will be stockpiled or sent to landfills. Theoretically, glass is a 100% recyclable material; it can be indefinitely recycled without any loss of quality. The construction industry has realized great gains in the recycling of industrial by-products and waste, including waste glass. Recycling of this waste by converting it to aggregate, not only saves landfill space but also reduces the demand for extraction of natural raw material for construction activity. Because these substitutes require extensive studies concerning their effect on the properties of concrete, a number of research studies have been performed and reported that the compressive, tensile, and flexural strengths of concrete containing waste glass as fine aggregate demonstrated a decreasing tendency with increase in the mixing ratio of the waste glass. found that 30% glass powder could be incorporated as aggregate or cement replacement in concrete without any long term detrimental effects.

2. EXPERIMENTAL PROGRAM

2.1. Materials

2.1.1. Cement

The cement used in this investigation was delivered from ''Ultra tech''. Testing of cement was carried out per the Indian Standard Specifications IS: 8112-1989. The mechanical properties of the used cement as determined by laboratory tests showed its suitability for concrete works. The mechanical properties of the cement used in this investigation are given in Table 1.

Table 1: Mechanical properties of cement.

S. No	DESCRIPTION	RESULT
1	Specific gravity	3.12
2	Fineness by sieve analysis	4%
3	Consistency	34%
4	Initial setting time	33min
5	Final setting time	168min

2.1.2 Fly ash

The flow ability of self compacting concrete depends on the powder and paste content. Hence, in order to increase the flow ability, mineral admixtures such as fly ash has been used. The fly ash used was obtained from Thermal Power Station India. The normal consistency of the fly ash was found to be 43%. Table 2 gives the physical properties of the fly ash.

Table 2: Physical Properties of Fly Ash

S. No	DESCRIPTION	RESULT
1	Specific gravity	2.1
2	Fineness by sieve analysis	4%
3	moisture	nil

2.1.3. Aggregate

Local dolomite and sand from natural sources were used in the experimental work. The used crushed dolomite has a nominal maximum size of 12 mm. Testing of natural coarse aggregate and sand were carried according to the Indian Standard Specifications The results are presented in Table 3.

Table 3: properties of Aggregate

S. NO	PROPERTY	Fine Aggerate	Coarse Aggerate
1	Specific gravity	2.613	2.625
2	Water Absorption	1.0%	0.5%

2.1.4. Recycled glass waste

Glass is widely used in our day to day life through manufactured products such as sheet glass, bottles, glassware and vacuum tubing. Glass is an ideal material for recycling. The waste glass was obtained from the dump of broken windows and doors panels. It was pulverized to get the particles ranging 4.75 mm and 0.075 mm in order to achieve the grading of fine aggregate. The different percentage of sand replaced by glass powder was 0%, 10%, 20%, 30%, 40%, and 50%.

Fig. 1 It was collected from glass factory wastes in India.

Table 4: Physical properties of Glass powder

S. No	DESCRIPTION	RESULT
1	Colour	white
2	Specific Gravity	2.2
3	Bulk density (t/m3)	1.34
4	Water absorption	0.57

Fig. 1: Recycled glass waste

2.1.5. Mixing water

Drinking water was used for mixing.

2.1.6. Super plasticizer

The chemical admixture used for the investigation is super plasticizer conplast sp430. In this experiment, 0.9% by weight of cement was used.

2.2. MIXES FEATURES

A total of 6 concrete mixtures were produced. All the mixtures were essentially self-compacting concrete, characterized by the same key features: W/C = 0.45, fly ash employment ratio (10%) addition to cement, and coarse aggregate to sand ratio = 1:1.

The cement contents were 416 and contains six mixtures corresponding to six replacement ratios of sand by waste glass (WG). These ratios were: 0%, 10%, 20%, 30%, 40%, and 50%.The first mix of each group with 0% waste glass (WG) replacement ratio was regarded as a control mix is given in table 5.

2.3. METHODS OF INVESTIGATION

2.3.1. Determination of the fresh properties

In this experimental work, the following fresh concrete tests were carried out:

(i) Slump-flow test for flow ability and viscosity, (ii) L-box test for testing passing ability, and (iii) V-funnel test for testing the filling ability of SCC provided that there is no possibility blocking and/or segregation to take place.

Slump-flow test procedure is a combination of Abrams' cone settling test. After lifting a filled and previously moistened metal cone, the final diameter of the circle formed by the spreading concrete is measured. The permissible diameter is 600–800} 50 mm, Fig. 2.

L-box test consists of the L shaped box, of a rectangular cross section, with a horizontal and vertical parts separated by the movable partition (exit) in front of which vertical rebars are arranged, Fig. 3. The vertical compartment is filled with concrete, then the partition is removed to allow the flow of concrete at the end of the horizontal part and of the remaining concrete in the vertical part are measured (H2/H1). That is an indicator of the capacity of concrete to pass through the rebars, and it should be as close to one as possible (the lowest permissible value is 0.8).

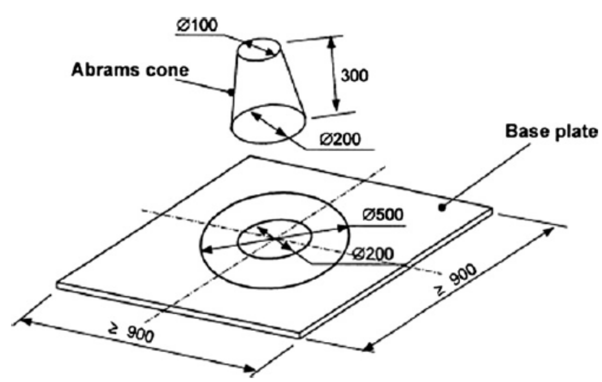

Fig. 2: Slump-flow apparatus.

V-funnel test, the funnel is filled with concrete, and the flow time, that is between opening the orifice and the first daylight appearing when looking vertically down through the funnel recorded and then filled the funnel after 5 min and recorded the time (Fig. 4).

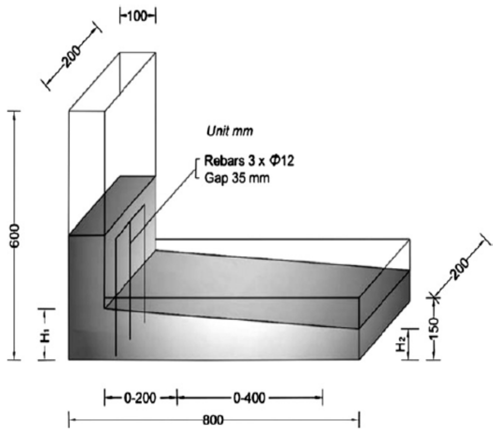

Fig. 3: L-box apparatus.

2.3.2. Determination of the hardened properties

In this research work, the following tests on hardened concrete were carried out:

a) Compressive strength: The compressive strength test was carried out according to the Indian Standard Specifications. To evaluate concrete compressive

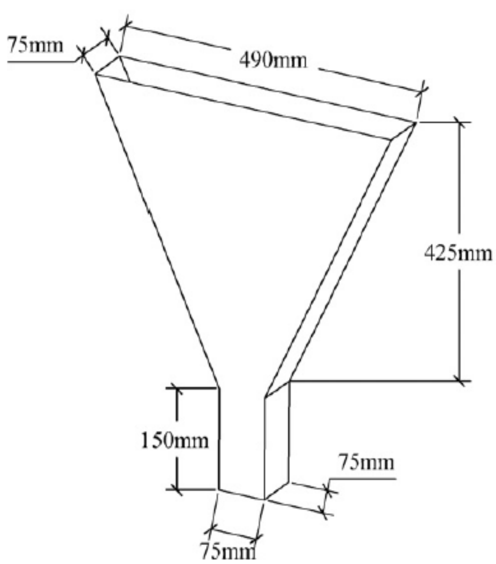

Fig. 4: V-funnel apparatus.

b) Splitting tensile strength: The splitting tensile strength test was carried out according to the Indian Standard Specifications. The splitting tensile strength at test ages of 7 and 28 days, cubes specimens 150 x 150 x 150 mm were tested. of standard hardened concrete cylinders, 150 mm diameter and 300 mm long, was obtained to evaluate concrete compressive strength at the ages of 7 and 28 days.

c) Flexural strength: The flexural strength test was carried out according to the Indian Standard Specifications. The flexural strength of standard hardened concrete beams 100 x 100 x 500 mm was tested evaluate concrete flexural strength at the ages of 7 and 28 days.

Table 5: Mix constituents for concrete mixture.

Categor y	W/C	C(Kg/m3)	Fly ah (%)	SP (%)	FA(Kg/m3)		CA(Kg/m3)
					Sand	WG	
MIX 1	0.45	416	10	0.9	900	----	831
MIX 2	0.45	416	10	0.9	810	90	831
MIX 3	0.45	416	10	0.9	720	180	831
MIX 4	0.45	416	10	0.9	630	270	831
MIX 5	0.45	416	10	0.9	540	360	831
MIX 6	0.45	416	10	0.9	450	450	831

3. RESULT AND DISCUSSION

3.1. Fresh concrete properties

The fresh properties of the 6 concrete mixes are summarized in Table 6, it can be seen that the initial slump flow of recycled glass SCC mixes was similar to control mixes although the dosage of super plastizer was decreased (see Table 5). This attributed to the weaker cohesion between the glass aggregates and the cement paste due to their smooth surfaces.

It can be seen from Table 6, the higher slump flow at higher glass replacements ratios could be also due to higher compactness of concrete granular skeleton. Because the glass grains are finer than the sand, it can fill better the porosity of the coarse aggregates, and has a low water absorption and smooth surface. All the mixes have slump flow over 650 mm and exhibit no segregation except mixes (M5 and M6) at cement content 416 kg/ m3 at percentage of replacements (40% and 50%) respectively, and this may be attributed to the lower paste volume (viscosity) achieved in these mixes. The importance of viscosity is generated from the fact that, increasing the viscosity maintains good suspension of coarse aggregate during deformation of the mixture. This can reduce inter-particle collision and coagulation of coarse aggregate particles. Hence, improve the ability of the grout mixture to properly fill the formwork and offset blocking. Also, increasing the viscosity enhances the bond between the mortar and coarse aggregate and thus, minimizes the risk of segregation.

As shown in Table 6, the flow ratios varied from 0.83 to 0.89, the results indicates that the recycled glass SCC mixes prepared in this study achieved adequate passing ability and maintained sufficient resistance to segregation around congested reinforcement areas this agree.

V-funnel test measures the time required for concrete to flow down through a funnel so as to evaluate cementing paste viscosity in concrete and resistance to material segregation. As shown in Table 6, the results followed to a great extent the trends observed in the slump flow test. At initial mixing the passing time becomes prolonged with increasing glass sand and this agree, thus decreasing the unit weight. Hence, the compacting effect cannot be attained by its dead weight. As a result, the Vfunnel test time was 9–19 s longer than that of the control group. However, the results still meet the flowability standard time.

Table 6: Fresh properties of concrete mixture.

Category	Slump Flow (Mm)	L-Box (%)	V-Funnel	
			After Mixing	After 5 Min
MIX 1	650	0.88	12	15
MIX 2	680	0.83	13	15
MIX 3	720	0.85	11	16
MIX 4	740	0.86	10	17
MIX 5	860	0.87	9	19
MIX 6	890	0.89	9	19

3.2. Hardened concrete properties

The test results of the compressive strength of the control and recycled glass SCC mixes at 7 days are summarized in Table7.that the use of recycled glass waste as a sand replacement decreases the compressive strength of the SCC mixes compared with the control mixtures. As shown in Fig. 5, the reduction in 28 days compressive strength of recycled glass SCC mixes. Where the high smoothness of recycled glass waste leading to cracks was determined to lead to incomplete adhesion between the recycled glass waste and cement paste inter-phase. who concluded that high degrees of strength enhancement were obtained when the pozzolanic effect became significant at the late age of 28 days.

The obtained splitting tensile strengths after 7 days are presented in Table 7. Each value is the average of measurements. Fig. 6 shows that the splitting tensile strength tends to decrease with the increases of the percentage of recycled waste glass replacement in the concrete mixture, compared with the control mixes. According to the test results the 7 days splitting tensile strength values are observed to at cement contents of 416kg/m3for replacement ratios of 10%, 20%, and 30%, respectively.

The results of flexural strength after 7 days are presented in Table 8, each value is the average of three measurements. As shown in Fig. 7, the flexural strength tends to decrease as the percentage of recycled waste glass replacement increases in the concrete mixture compared with the control mixes. According to the test results, the 7 days flexural strength values are observed to decrease at cement contents of 416 kg/m3 for replacement ratios of 10%, 20%, and 30%, respectively.

Table 7: Harden properties of concrete mixture.

Designation	Compressive Strength (N/mm2)		Splitting strength (N/mm2)		Flexural strength (N/mm2)	
	7 days	28 days	7 days	28 days	7 days	28 days
MIX 1	35.2	46.4	4.7	10.2	5.6	14.7
MIX 2	33.1	43.6	4.3	9.8	5.3	14.3
MIX 3	31.6	41.6	4.3	9.7	4.8	14.5
MIX 4	30.9	40.5	4.2	9.1	4.6	13.9
MIX 5	29.5	38.3	3.8	8.8	4.8	13.4
MIX 6	26.5	35.7	3.1	8.5	4.2	13.2

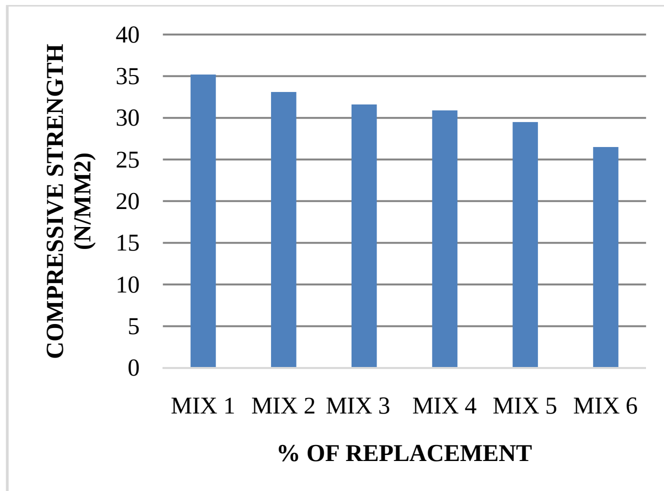

Fig. 5: Compressive strength (N/mm^2)

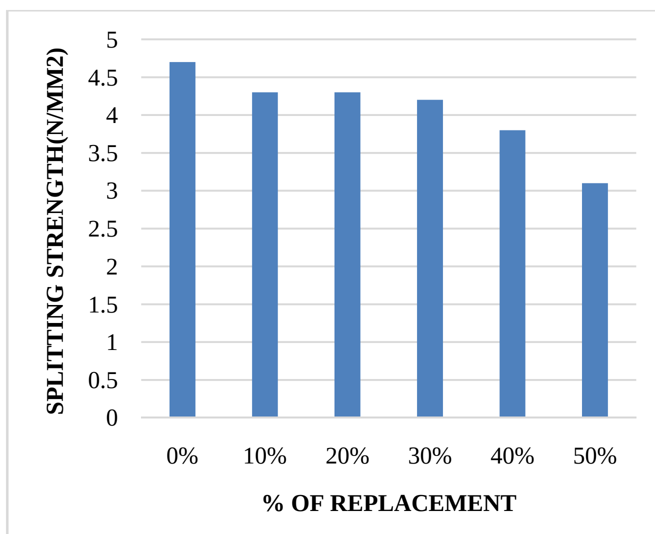

Fig. 6: Splitting strength (N/mm^2)

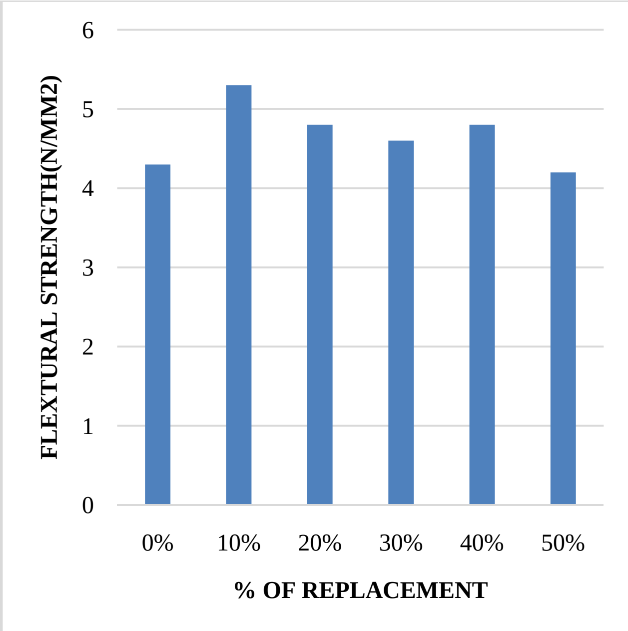

Fig. 7: Flexural strength (N/mm^2)

4. CONCLUSIONS

1. The slump flow, flow ratio, and V-funnel of recycled glass SCC mixes increases with the increase of recycled glass content. The flow ratios varied from 0.83 to 0.89.
2. The compressive strength, splitting tensile strength, and flexural strength of recycled glass SCC mixes decrease with the increase of recycled glass content in 28 days.

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